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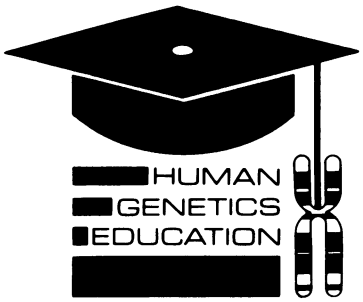

Re-Aiming the Canon

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Summary

Although it is unlikely that the national goals for educational reform—such as that, by the year 2000, U.S. students will be first in the world in science and mathematics achievement—can be achieved, a vigorous effort must be made to reach those goals as rapidly as possible. Reform will come not from a massive expansion of what we now do but from a basic shift in the manner in which we educate students in grades K–16 in the sciences and mathematics. Important elements in that basic shift must include an increase in teaching of science, mathematics, and technology (SMT), to about 20%–25% of the curriculum; SMT must include rich hands-on experiences, with an emphasis on concepts and understanding, rather than on facts and memorization, and on how science as a way of knowing differs from other ways of knowing; SMT must consider human problems; and SMT must deal with the basic problem facing humanity—how we must adjust our behavior so as not to exceed, on a worldwide basis, the carrying capacity of the environment.

Knowledge of science, mathematics, and technology (SMT) is now recognized as vital for maintaining the nation's infrastructure, industry, and worldwide competitiveness, for efficient utilization of resources, and for protection of the environment. It can be argued that such knowledge need not be possessed by all citizens, but a critical mass of leaders in government and industry must have an adequate background in SMT to be able to deal with a host of societal problems. But surely all should have a degree of understanding that will enable them to live a meaningful life in a world dominated by science and technology.

There is abundant evidence that the educational system is not fulfilling these needs (National Commission on Excellence in Education 1983; National Science Board 1983, 1989; Mullis and Jenkins 1988; American Association for the Advancement of Science 1989; Lapointe et al. 1989; National Research Council 1990; Carnegie Commission on Science, Technology, and Government 1991; Department of Education 1991; SCANS 1991). We are bombarded by these reports that place our students among those of the developing nations in knowledge of science and technology. And, of course, the schools pay almost no attention at all to technology.

We find that the vast majority of students enter the world of adult life knowing little and caring less about science. George W. Tressel (Tressel 1991) reports that most of the public do not want to know about science; they are preoccupied with other things, such as money. He estimates that 20% are attentive to science, 20% find it interesting but do not seek it out, and 60% do not care about it or about almost *anything*.

Although the magnitude of the problem is recognized, it is not clear that the magnitude of the solution is also recognized. We cannot achieve success by doing more of what we are now doing. Instead, there must be a radical change in the quality and quantity of SMT education.

Among the many problems afflicting higher education in the United States is a pervasive lack of agreement about what should be taught and in what manner it should be taught. The canon that has served for generations and that has been regarded as the hallmark of an educated person has been called into question as inadequate or even evil. The complaint is that for far too long the emphasis has been on Western civilization, which critics are wont to say is the creation of dead, white, European males.

Many of the major universities are beset by the challenges of those who wish to change the traditional canon. It is proclaimed by some that all standards are

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arbitrary and that there is no objective reality (D'Sousa 1991).

But in science all points of view do not have equal standing. There is good science and there is bad or inadequate science. Good science permits more satisfactory and confirmable explanations of natural phenomena than does bad science. Science gets progressively better because its data, hypotheses, and concepts are constantly evaluated and upgraded by new minds and new discoveries. The genetics of Darwin in 1859 is crude and inadequate in comparison with the genetics of Mendel in 1900, which was replaced by the genetics of Morgan in 1920, and, finally, by the highly sophisticated genetics of today.

There are no movements, so far as I know, to change the canon of science or to rewrite anything other than the details of its history. Nevertheless I believe there must be a drastic change in the canon, a change that seeks to provide the knowledge of science and technology that is thought necessary for our students. We must re-aim the canon.

In the current ferment about the wretched state of K–12 education in the United States, numerous committees and commissions say that something must be done, but there is a dearth of anything being done. There is a general feeling that lack of funding is the main problem and that, with a massive inflow of funds, the educational system can be put right. I doubt it. If the system is at fault, and I believe that it is, more funds may serve mainly to expand what is faulty (see Goldsmith 1992).

The systemic problems with American education are a lack of an effective program to achieve the stated goals and an almost total lack of understanding of the magnitude of the task. The President and the governors have listed six main goals to be reached by the year 2000. Number 4 states: "U.S. students will be first in the world in science and mathematics achievement." Let us consider what would be required to achieve that goal.

First, we have to recognize how little time is available. Students who will graduate from high school in June 2000 are already in the pipeline. They finished the fourth grade last June and are now well into the fifth grade. They are progressing through a system that has been failing in recent years and that shows little or no improvement. What can possibly change so that, by the time they graduate in June 2000, they will lead the world in science and technology and, of far greater importance, will be competent to keep our society functioning at a high rate of effectiveness? One can note with some sadness and a sense of deja vu that in 1983 the National Science Board Commission (1983) proposed "a plan of action for improving mathematics, science and technology education for all elementary and secondary students so that their achievement is the best in the world by 1995." If anything, the situation is worse today than it was in 1983.

This simple analysis suggests that a sea change is required, and my suggestions for the shape of that change follow. First, effective education in science and technology will require that 20%–25% of the time and effort spent in the K–16 classrooms be devoted to science and technology—this means all sciences and much technology, which should be programmed for the level of sophistication of the students—and to reducing any redundancy that does not promote effective learning and retention.

Many wedded to the status quo will quail at that 20%–25%. But can we do with less? If SMT is to be taught in an inquiry mode, with students having a maximum opportunity for discovery in laboratory, field, community, and library and for reaching their own conclusions, much time is required. SMT need not replace what is now in that other 75%–80% of the curriculum. Students can read, write, spell, speak, and think in SMT as well as—or, more likely, better than—they can in special classes for reading, writing, etc. SMT can and should be a powerful device for integrating the curriculum. Special attention must be paid to K–6 students, who seem to have an innate interest in science and an ability to profit from hands-on experiences. *They* should have the very best science teachers.

Second, the approach to science should emphasize science as a way of knowing; distinguish this from other ways of knowing; seek the overarching concepts of science and not emphasize facts for facts' sake. Students must come to realize that science cannot decide what human beings should do. Human goals must be chosen by human beings for whatever reasons, but, once goals have been selected, science and technology can be powerful devices for achieving those goals. For example, amniocentesis may reveal a severe abnormality, but the response to that biological information must be a human decision.

Third, every effort should be made to relate science and technology to immediate human and personal problems and to the student's understanding of the world. The fourth suggestion, and probably the most important reason of any for education in the sciences and technology, is to explain why the human popula-

tion must begin to live within the carrying capacity of the environment. Unless we do that, the human species has no future, and, in time, we may well return the world to the prokaryotes.

There is no way these goals can be reached by the year 2000—and no way at all if we merely continue to do more of what we now do. So, what must be done?

One of the most obvious requirements is a vast increase in the number of science teachers. If 20%–25% of the curriculum is to be devoted to science, in contrast with the present amount, which is usually less than 5%, many new teachers will be necessary, and they must be educated in ways very different from the current practice. And they must be much better teachers. A recent Carnegie Commission report (Carnegie Commission on Science, Technology, and Government 1991, p. 20) quotes the National Science Teachers Association as believing that 97% of elementary teachers are inadequately educated in science and mathematics. Another study suggests that the percentages of inadequate science teachers in elementary, middle, and high school are 67%, 59%, and 71%, respectively. The corresponding percentages of inadequately educated mathematics teachers are 82%, 86%, and 88%, respectively.

We must so change society—and society's view of education—that K–12 teachers begin to come from the upper quartile of college and university students. That means the teaching profession must be made much more attractive than is now the case. Education is one of the most important features of a civilization, and the rewards of teaching must reflect that fact.

Since the origin of these new teachers must be the colleges and universities, the colleges and universities must be a key to any sustainable educational reform. Higher education must encourage the very best students to consider a career in K–12 education and then must design courses to prepare them properly for a much expanded and very different sort of education in science and technology.

One of the most important impediments to educational reform must be removed—i.e., the firm belief in the virtues of decentralized education. Somehow, national curricula and meaningful standards for students and teachers must be accepted. This will require some nationwide nonpolitical group to provide materials, guidance, support, and standards; to exert political pressures for education; and to try to prevent the turf battles that still impede educational reform. The National Academy is currently exploring this idea.

Systematic and sustainable educational reform requires no new discoveries. We have good models of teachers and classrooms that work. The hard tasks will be to agree on goals and then to unite to work for them. The tasks will be hard because an effective outcome will require (*a*) substantial changes in how adults view the schools, (*b*) a willingness to accept the social and political changes that will give the nation the schools it deserves, and (*c*) a very great deal of hard work on the part of those who teach in the K–16 classrooms.

It may sound overly dramatic, but I will argue that the welfare of our nation and the world as a whole requires that a critical mass of individuals and their leaders possess a deep understanding of how science gives order to the seeming chaos of nature, of the strengths and limitations of its procedures, and of its applicability to achieving our goals. Science and technology must become the core of a liberal arts education. There can be no liberation for those who remain ignorant of the beauty, strength, creativity, and essentialness of these twin disciplines.

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